Preparation and Property Evaluation of Bamboo/ E-Glass Fiber Reinforced Polymer Composites

[1]Diwakar Reddy B, [2]Praneeth D, [3]Praveen Kumar, [4]Raghu Nandan G, [5]Venkatesha B K
[1,2,3,4] U G Students, School of Mechanical Engineering, REVA University, Bengaluru
[5]Assistant Professor, School of Mechanical Engineering, REVA University, Bengaluru

Abstract:
Fly ash is a fine powder that is a byproduct of burning pulverized coal in electric generation power plants. Recent days there has been a greater importance towards development of natural fiber reinforced polymer composites because these are environmentally friendly and cost effective to synthetic fiber reinforced composites. But, natural fiber reinforced composites are the poor resistance to absorption of moisture. Due to this problem, a natural fiber may be combined with a synthetic fiber with the same matrix material so as to achieve the best advantage in enhancement of their properties. In this connection, hybrid composite materials of natural and man-made fibers reinforced polymer composites are essential for current demands. This study is to evaluate the effect of flyash addition on mechanical properties of Bamboo and E-Glass fiber reinforced composite materials. The mechanical properties are tensile strength, flexural strength & ILSS were to be tested as per ASTM standards. Composite with 2% of flyash shows maximum tensile strength and 1.5% flyash shows maximum flexural strength and ILSS strength.

Keywords: **Flyash, epoxy resin, hybrid composite, mechanical properties, ASTM standards.**

I.INTRODUCTION

Polymeric materials reinforced with synthetic fibers such as E-Glass, Carbon, Kevlar and Aramid provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials. Despite these advantages, the widespread use of synthetic fiber reinforced polymer composite has a tendency to decline because of their high initial costs, and most importantly their adverse effect on environmental issues [1]. Natural fibers exhibit many advantageous properties such as low density materials, yielding a relatively lightweight composite with high specific properties. Therefore, the increased interest in using natural fibers in plastics to substitute conventional synthetic fibers in some applications has become one of the most concerns to study the potential of using natural fibers as reinforcement for polymer matrix composites [2-3]. The main disadvantage of natural fiber composites is the poor resistance to moisture absorption. Hence, the use of natural fiber alone in polymer matrix is inadequate in satisfactorily tackling all needs of fiber-reinforced composites. Due to this, a natural fiber can be combined with a synthetic fiber with the same matrix material so as to take the best advantage of the properties of both natural and synthetic fibers. This idea results in a hybrid composite and having increased mechanical properties than natural fiber reinforced material [4-5]. Jayabal S, et.al. [6] evaluated the mechanical properties of woven coir and compared results of woven coir/glass fiber reinforced polyester composites. The results predicted that the properties of woven coir composites were significantly improved by incorporation of glass fibers. Sanjay M. R., et. al.[7] investigated the mechanical properties of laminates prepared of different composition of banana and glass fabrics in polymer composites. Results indicated that pure glass fabric laminate showed higher tensile strength and flexural strength when compared with pure banana fabric laminate. Sneha Latha P, et. al.[8] studied the effect of stacking sequence of mechanical properties of woven bamboo/glass fabric reinforced polymer hybrid composites. The results indicated that the properties of bamboo fiber reinforced composites were significantly improved by incorporation of glass fibers in polymer matrix composite. Biswas S., et. al.[9] investigated the effect of fiber loading and fiber orientation on mechanical and erosion behavior of glass fiber reinforced epoxy composites. The results revealed that, the composite with 30^0 fiber orientation showed better micro hardness compared with other fiber orientations, and 60^0 fiber orientation showed superior tensile modulus and impact energy, where as tensile strength, and flexural strength, showed better results in 15^0, 30^0, and 15^0 fiber orientations with the increase in fiber loading. B. Stanly J.R., et. al.[10] studied hybrid bamboo/glass woven fabrics in different orientations such as 0°/90° and ± 45°. The hybrid specimen with ±45° orientation yielded higher tensile strength and flexural strength when compared with 900 fiber orientation. Vijaya Ramnath B, et.al. [11] evaluated the mechanical behavior of a jute-flax based glass fiber reinforced composite. The results revealed that the hybrid composite exhibited good mechanical properties. P. Sathish, et.al.[12] studied the effect of fiber orientation and stacking sequence on mechanical characteristics of banana/kenaf hybrid epoxy composites. The results showed that the hybrid composite with 45^0 fiber orientation had better properties than the other orientations. Mohaiman J. Sharba, et. al.[13] investigated the effect of fiber orientation on mechanical properties such as tensile strength, compression strength, and flexural strength of Glass/Kenaf hybrid composites. The results predicted that non-woven random mat Kenaf hybrid composite exhibited poor mechanical properties with other composite mats. Mahmud Zuhudi, et.al.[14] evaluated the mechanical, thermal and impact performances of the bamboo fabric-reinforced polymer composites. The results significant at the 50 wt.% of bamboo contents, where the tensile strength and its modulus were increased 238% and 100% compared to neat PP, respectively. Similarly, the flexural strength and modulus contributed to about at least 170% increase over the neat polypropylene. Venkatesha B K, et.al.[15-17] studied the mechanical properties of bi-directional Bamboo and E-Glass fiber reinforced epoxy hybrid composites. Results are revealed that composite laminate with $0/90^0$ fiber orientation shows better tensile strength compared with 45^0 fiber orientations. Similar observations are also presented for other mechanical properties of the composites such as flexural strength, inter-laminar shear strength, and micro-hardness. The morphology of tested tensile surfaces are examined using scanning electron microscopy (SEM), and possible fracture mechanisms are identified. Soma Dalbehera and SK Acharya [18] studied the effect of Cenosphere addition on the mechanical properties of jute-glass fiber hybrid epoxy composites. The mechanical properties are significantly influenced by addition of cenosphere up to 1.5 wt% and increases the tensile, flexural and inter-laminar shear strength by 90.47%, 24.32% and 16.75%, respectively, in comparison to unfilled composite. The morphologies of the composites studied by scanning electron microscope indicate good dispersibility of cenosphere in the matrix, which in turn improves the strengths appreciable.

Against this background, the present investigation has been undertaken to study the effect of Flyash addition on the mechanical behavior of bi-directional bamboo and E-Glass fiber reinforced hybrid epoxy composites.

II. EXPERIMENTAL PROCEDURE

A. Materials

In the present investigation, bi-directional E-Glass fiber was supplied by the Vijay trading corporation, J.C. Road, Bengaluru, India. Woven Bamboo fiber was procured from Jolly Enterprise, Kolkata, West Bengal (India). The plain weave E-glass with an areal weight of 210 g/m^2 and Bamboo with an areal weight of 230 g/m^2 was used to develop the hybrid laminates. Figure 1 shows the bi-directional Bamboo and E-Glass fiber mat used during fabrication of samples. The epoxy resin used in the investigation was general purpose quick curing, medium viscosity epoxy resin HSC 7600 and the hardener used was HSC 8210. Both resin and hardener procured from the Hindusthan Urban Infrastructure Ltd. (HUIL), Kolkata, West Bengal (India).

Figure 1 Bi-directional woven Bamboo and Glass fiber

B. Preparation of composite laminates

Fabrication of the composite laminates was done by usual conventional hand lay-up technique followed by light compression molding technique. The mould was prepared with mild steel of size 310*310 mm^2. It contains of two mild steel plates, lower die with rectangular slot and upper die with flat surface. Initially the mould was thoroughly cleaned by thinner solution and then coated with release agent used to facilitate easy removal of the composite from the mould. The mould was allowed to dry for 25 minutes. The composite laminate consists of seven layers of glass and six layers of bamboo fibers were placed alternately until the desired thickness might achieved. Woven bamboo fibers and glass fibers were arranged with respective to the base fiber. The laminates were prepared from bamboo and glass fabrics of particular dimension 300*300*5 mm^3. The epoxy resin was mixed with hardener in the proportion of 10:1 as recommended by manufacturer and then poured onto each layer of woven fabric and remove entrapped air bubbles if present. Both lower and upper dies were tightened with C-Clamps. Curing was done at room temperature for approximately 30 hours. As soon as the curing was completed, mould was opened and the laminate was taken out carefully. The same procedure was repeatedly followed to make other composite laminates with addition of flyash additions in terms of weight basis such as 0.5, 1, 1.5 and 2 wt% of composite.

C. Mechanical Properties of Composites

Tensile test: The most basic type of mechanical test that is commonly performed is tensile. Deformation can be measured by stretching a material in opposite direction. A complete tensile profile will be obtained as it is continued to stretch until it breaks. The simplest mathematical formula of stress,

$$\sigma = \frac{F}{A} \text{ in N/ mm}^2$$

Where, $A =$ initial cross sectional area, $F =$ the applied tensile load.

Rectangular shaped specimens were cut from the composite laminates with a length 250 mm, width 25 mm using the power hacksaw machine and the edges were smoothed and finished to the required dimensions. Tensile tests were conducted according to ASTM-D3039 standard testing procedure using a computerized Universal Testing Machine. Specimens were placed in the grips and pulled at a constant strain rate of 5 mm/min until failure occurred.

Flexural test: This test is performed using 3-point bending test on rectangular specimens according into ASTM-D790. Specimens were cut from the composite laminates with a length 130 mm and width 14 mm using the power hacksaw machine. The specimens were tested with a crosshead speed of 5 mm/min. The edges were smoothed and finished to the required dimensions of both tensile and flexural test specimens. Five specimens of each composite were tested for accuracy and then mean of the tensile strength and flexural strength was reported. The flexural strength (FS) was determined by using the following equation,

$$FS = \frac{3PL}{2wt^2} \quad \text{---------------------------(1)}$$

Inter-Laminar Shear Strength (ILSS): It is also evaluated to help of data recorded during 3-point bend test as per ASTM 2344 and ILSS is determined by using the following equation,

$$ILSS = \frac{3P}{4\,wt} \quad \text{----------------------- (2)}$$

Where, **P** is the maximum load in N, **L** is the span length of the sample in mm, **w** is the width of the specimen in mm, **t** is the thickness of the specimen in mm

III. Results And Discussion

In this study, the effect of flyash addition on mechanical properties of woven Bamboo and E-Glass fiber reinforced epoxy hybrid composites are evaluated and compared. The results of the tensile, flexural and ILSS testing of the composite laminates are presented in the Table 1.

Table 1 Mechanical Properties of Bamboo and E-Glass fiber reinforced composites with flyash

Sl. No.	Percentage of Flyash (wt.%)	Ultimate Tensile Strength (MPa)	Flexural Strength (MPa)	Inter Laminar Shear Strength (MPa)
1	Epoxy	19.13	3.65	2.68
2	0	83.45	8.85	6.98
3	0.5	95.15	10.09	7.75
4	1	108.17	11.02	7.3109
5	1.5	110.02	12.06	9.53
6	2	114.86	14.12	8.645

A. Effect of Fly ash on Tensile test

Tensile Strength for composite laminates with Fly ash filler filled bamboo-glass hybrid epoxy composite are presented in Figure 2. The maximum tensile strength of 113.67 MPa was observed in 1.5 wt.% of Flyash based composites.

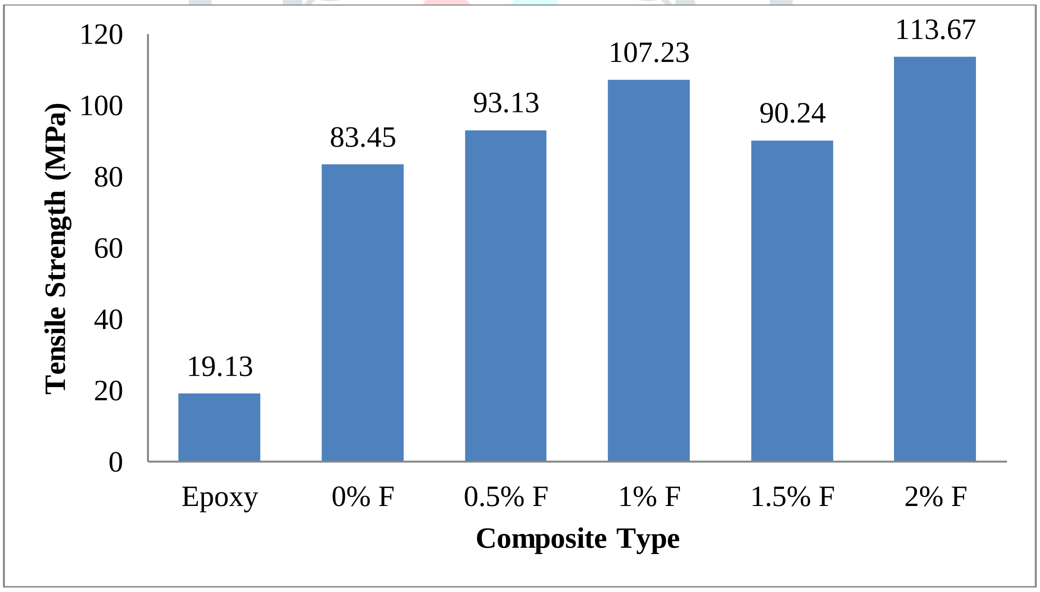

Figure 2 Tensile strength of Fly ash filled bamboo-glass hybrid epoxy composites

B. Effect of Fly ash on Flexural Test

Flexural Strength for composite laminates with Fly ash filler filled bamboo-glass hybrid epoxy composite are presented in Figure 3. The maximum flexural strength of 12.13 MPa was observed in 1.5 wt.% of Flyash based composites.

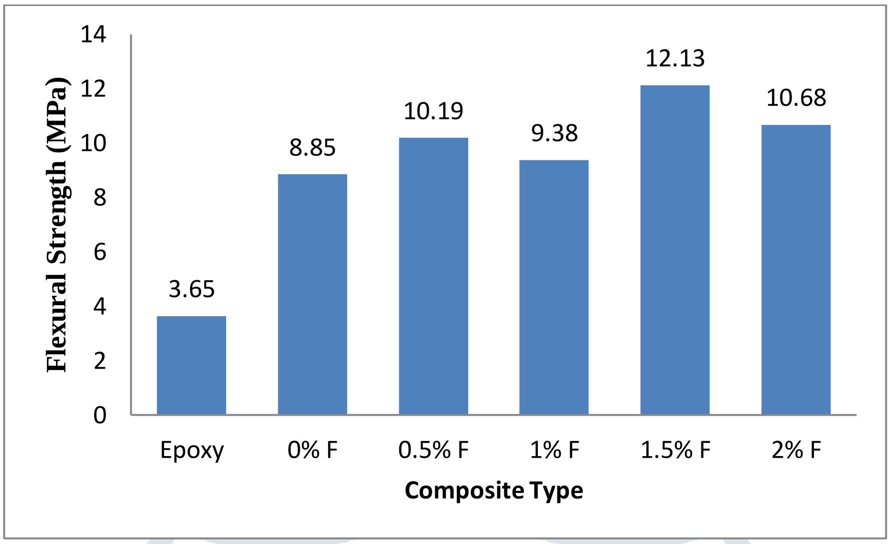

Figure 3 Flexural strength of Fly ash filled bamboo-glass hybrid epoxy composites

C. **Effect of Fly ash on Inter-Laminar Shear Strength**

Inter-Laminar Shear Strength for composite laminates with Fly ash filler filled bamboo-glass hybrid epoxy composite are presented in Figure 4. The maximum inter-laminar shear strength of 9.53 MPa was observed in 1.5 wt.% of Flyash based composites. Also we observed that addition of Fly ash filler on bamboo- glass hybrid composites increases the inter laminar shear strength.

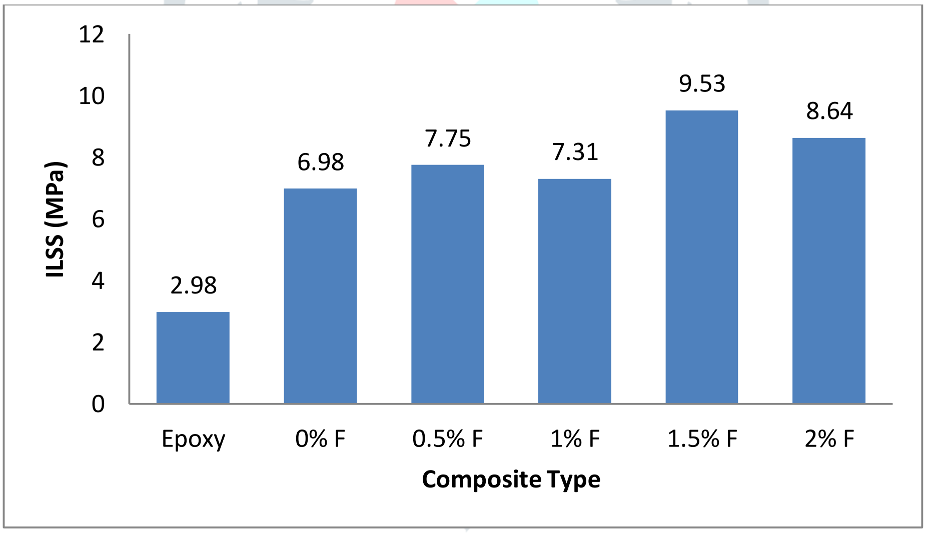

Figure 4 ILSS of Fly ash filled bamboo-glass hybrid epoxy composites

IV. CONCLUSIONS

Based on the study of the mechanical properties of bamboo and glass hybrid epoxy composites with varying weight percentage of Fly ash addition, the following conclusions are made:

1. The successful fabrication of bamboo-glass hybrid fiber reinforced epoxy hybrid composites with Flyash filler was possible by simple hand lay-up technique.
2. Effect of Fly ash filler on tensile and flexural properties of bamboo-glass fabrics reinforced epoxy composites indicates that incorporation of filler enhanced the mechanical and flexural properties.
3. Maximum tensile strength was observed for the composite with inclusion of 2 wt% Fly ash filler.
4. Maximum flexural strength and ILSS was observed for the composite with addition of 1.5 wt% Fly ash filler.
5. The increase in tensile strength with 2 wt% of Flyash filled composite is found to be 26.58% higher than that composite without filler.
6. The increase in flexural strength and ILSS with 1.5 wt% of Flyash-filled composite is found to be 27.04% and 26.75 % higher than that composite without filler.

This work can be further extended by introducing any filler materials in the epoxy matrix and also using various bio-degradable resins. Instead of the hand lay-up technique, other manufacturing techniques may be adopted to improve the mechanical properties of the composites.

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